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Wireless and Optics – A Survey and Overview of Broad Band Fiber-Fed Radio Systems

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Abstract – This paper was prepared for NATO's RTA Lecture Series No. 229 presented at the workshop of Optics-Microwave Interactions held in September 2002. This lecture reviews recent developments of fiber-fed radio systems, an emerging technology using fiber optic networks to distribute broad band RF and MMW signals for mobile and wireless systems over long distance and within small cells.

This lecture note is a supplement to the vugraphs package (see attachment) presented at the workshop. Basically, it is a condensed version of the text portion (annotation) attached to the vugraphs (Power Point charts).

What is "Fiber Radio?" Fiber Radio is a fiber-fed radio system using fiber optic links or networks to distribute video, voice, and data for mobile and wireless applications. Antenna remoting is an example where MMW subcarriers at 18, 24, 38, or 60 GHz with information are transmitted from central office to base stations. This emerging technology has been demonstrated for applications such as community communications and pico-cell wireless systems for both uplinks and downlinks broadcast carrying CATV, WLAN signals and data ranging from 2 to 156 Mbps.

According to a McKinsey report, August 2001, the market trend for this industry is hard to predict at this point. In general, the telecom markets have slumped for the last few years. The slowdown was caused by over-capacity and unrealistic forecast. Numerous start-ups were funded five years ago, but many stocks dropped by 80 percent or more in value since then. Many US companies have suffered great losses. However, the demand for broad band services is for sure increasing. It is estimated that the growth rate may reach 25 percent a year. Thus the over-capacity or glut may be absorbed in a few years. It can be safely remarked that the "fiber-radio" technology is attractive, but it is not a huge mature market yet.

1. Applications of Fiber-Radio Systems

Several fiber-radio system architectures have been studied and demonstrated. A typical infrastructure concept was reported by Wake, et al [Optical Generation of MMW Signals ... in IEEE Trans. MTT, p.2270, 1995]. He described a system where an optical fiber system with optical couplers (splitter) was used to distribute radio signals with MMW subcarriers broadcast over many pico-cells (200 m range) for community services.

Paper presented at the RTO SET Lecture Series on "Optics Microwave Interactions", held in Jouy en Josas, France, 2-3 September 2002; Duisburg, Germany, 5-6 September 2002; Budapest, Hungary, 9-10 September 2002, and published in RTO-EN-028.

More details of similar system concepts were provided by Ogawa el al [MMW Fiber Optic Systems for Personal Radio Communications, IEEE Trans. MTT, p. 2285, 2002]. They studied and conducted an experiment reporting that excellent performance of IF links with 70 MHz QPSK and 300 MHz FM on 26 GHz subcarriers were obtained. For downlinks from central office to base stations, several modulation schemes were discussed. For uplink from base stations to central office, low frequency lasers and photodetectors could be utilized because data rate and traffics were not as high as downlinks.

Han, Kim, and Chung at Korea Advanced Institute of Science and Technology studied a multi-purpose fiber optic access network, where CATV, PCS, and base band signals were multiplexed and carried by 10 km optical fibers to various nodes for distribution. They presented the RF performance of various services with geographical and technical specifications.

Ahmed, et al [37-GHz Fiber-Wireless System for Distribution of Broad Band Signals, IEEE, MTT, p. 1431, 1997] conducted an experiment using 36 GHz carriers to broadcast audio, video, and CATV signals over short distance, establishing the feasibility of fiber-radio links for wireless systems.

Fiber-fed radio systems can also be used to study the geographic arrangement of base stations for optimum reception. Arrendonda, et al [Techniques for Improving In-Building Radio Coverage Using Fiber-Fed Distribution Antenna Networks, IEEE AP-S Symp, p. 1540, 1996] conducted a statistical study on diversity, placement, and number of antennas in a fast fading Rayleigh environment for performance improvement. They compared systems and data characteristics at 900 MHz, 1.8 and 1.9 GHz, and found that multiple distributed antennas improved coverage, reduced dynamic range required, and eliminated deep fades.

Fiber-fed radio systems may include a photonic network to distribute local oscillator signals. High frequency channels with external modulators and low frequency channels with direct modulators can be combined and distributed through the optical fiber system for various mixing and conversion functions. Photonics will be a key technology to reduce the size and weight of a complex LO distribution system for broadcast, multicast, or point to point connections.

2. Components of Fiber-Radio Systems

Several charts are included to cover the components of the fiber-fed radio systems, including MMW sources, transmitters, modulators, WDM, couplers, amplifiers, and detectors.

To be reviewed first are the schemes and performance issues of antenna remoting using direct and external modulators in the photonic links. The talk will discuss how to improve link performance with increase of laser power and photodetector output current in a link with external modulator for MMW subcarriers distribution.

To overcome the difficulty in producing high quality MMW sources by conventional RF means, one may consider optical generation by heterodyne methods (beating two optical lines) or using mode-lock lasers. Vieira et al [A Mode-Locked Microchip Laser Optical Transmitter for Fiber Radio, IEEE MTT, p. 1882, 2001] offered such a solution.

At the output side of the link, extracting 60 GHz MMW signals with a photodetector is not an easy task when efficiency, cost, and reliability are taken into account. One example was given by Rohde el al [Optical-MMW Converter for 60 GHz Radio-over-Fiber Systems.]

JDS Uniphase is one of the major companies developing key photonic components for photonic and fiber-fed radio systems. A complete photonic network requires many components, including laser sources, modulators, dense WDM, couplers (optical splitters), amplifiers, optical switches, etc. Examples will be given to realize the dimension and complexity of the key devices required for the system.

3. Issues and Performance Parameters of Fiber-Radio System

Several charts are provided to recognize the fact that the performance of a photonic or fiber-fed radio system will be judged by the same set of parameters commonly used and defined by the RF designers. These are gain, noise figure, signal to noise ratio, dynamic range, bandwidth, third order intercept point, etc. Photonic links with COTS (Commercially Off The Shelves) components for wide band and narrow band requirements will be compared with a standard RF amplifier channel using typical wide band COTS devices. It can be seen that it is still a challenging task to develop a photonic link that can compete with a conventional RF channel using the same set of performance parameters mentioned.

It can be summarized that fiber-radio is an emerging technology that will become more attractive to distribute MMW broad band signals for wireless and mobile applications. The demand for such systems is increasing for regional and community networks, but so far no major venture capitals are rushing into the market yet. In other words, no market "pain" or "killer application" has been identified to foresee a major shift in the market trend for such products. Technology for laboratory demo is maturing, but lot more product development is required to produce low cost and robust (reliable) MMW and RF photonic components. In addition, it is necessary to further improve the performance of fiber optic links for RF designers to accept and use photonics. There are many photonic scientists, but it appears that engineering schools need to train more students to become photonic system engineers.